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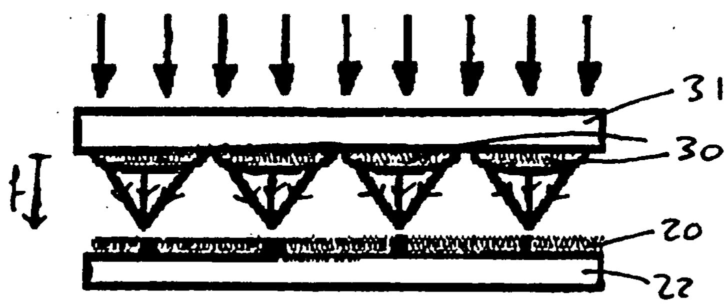

(57) Abstract

A photomask arrangement comprises an array of optical elements (30) (e.g. microlenses) arranged to receive a uniform beam of light and to concentrate light onto respective points, lines or other areas of a photoresist layer (20). In this way, the light passing through each optical element is converged or concentrated onto a smaller area, thus maximising the use of the available light.

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PHOTOLITHOGRAPHY MASKING ARRANGEMENTS

The present invention relates to photolithography and more particularly to masking or imaging arrangements for imaging a pattern onto a photoresist coating.

There are a number of applications where it is required to image an array of dots or other shapes onto a photoresist coating. One example is in the formation of arrays of field emitters for a field emission display type of flat panel display. Hitherto, a conventional photomask has been used, comprising a glass plate having a chromium coating which has an array of apertures corresponding to the dot matrix to be formed on the photoresist coating on a separate substrate. Light is passed through the photomask and transferred onto the photoresist coating, but the major part of the light is blocked by the chromium coating, so that the process is relatively inefficient.

We have devised improved photomask arrangements which are substantially more efficient.

In accordance with the present invention, there is provided a photomask arrangement which comprises an array of optical elements and means for providing a uniform beam of light incident on said array, each optical element being arranged to concentrate light onto a respective point, line or other area of a photoresist layer.

The optical elements may take any of a variety of forms, for example refractive or diffractive microlenses (e.g. spherical, cylindrical or elliptical in shape), diffraction gratings, apertures etc. Where the optical elements comprise lenses, each lens causes the light passing through it to converge onto an area of smaller size than the lens itself. The lens array may be in direct contact with the photoresist layer, or it may be positioned at a small distance from the photoresist layer.

Each lens (or other optical element) may have a diameter generally in the range 2 to 500 microns, more typically in the range 2 to 50 microns. Instead of being circular, the lenses or other optical elements may be of any

other desired shape (e.g. cylindrical, annular, square, rectangular, elliptical, etc.) and arranged to form an array of dots, lines, circles, squares, rectangles etc. on the photoresist coating.

The photomask arrangement may make use of the self-imaging effect (Talbot effect) to image the periodic mask pattern onto the photoresist, when the latter is positioned at the Talbot distance (or a multiple of the Talbot distance) behind the mask.

The photomask arrangement may make use of the fractional Talbot effect to image the mask pattern onto the photoresist, when the latter is positioned at a fraction of the Talbot distance behind the mask. In this case the photomask preferably comprises a binary phase mask.

An advantage of the arrangements which use the Talbot effect or the fractional Talbot effect is that in these cases the substrate with the photoresist is positioned at a significant distance from the photomask: in certain applications this is a necessary or desirable condition.

Embodiments of the present invention will now be described by way of examples only and with reference to the accompanying drawings, in which:

FIGURE 1 is a diagrammatic sectional view through a conventional photomask arrangement;

FIGURE 2 is a similar sectional view through a first embodiment of photomask arrangement in accordance with the present invention;

FIGURE 3 is a diagram to show the distribution of light waves behind each lens of the photomask shown in Figure 2;

FIGURE 4 is a sectional view similar to Figure 2, showing a second embodiment of photomask arrangement in accordance with the invention, which uses the self-imaging effect (Talbot effect); and

FIGURE 5 is a similar sectional view, showing a third embodiment of photomask arrangement in accordance with the invention, which uses the fractional Talbot effect.

Referring to Figure 1, there is shown a conventional photomask arrangement, in which a uniform beam of UV light is passed through a photomask 10 onto a photoresist coating 20 on

a substrate 22. The photomask 10 comprises a glass plate 10 having a chromium coating 11 which is formed with a two-dimensional array of openings. It will be appreciated that only a small proportion of the UV light passes through the openings of the chromium coating 11 and onto the photoresist coating 20 of the substrate 22: the major proportion of the light is blocked by the chromium coating 11.

Figure 2 shows a photomask arrangement in accordance with the present invention, comprising a two-dimensional array of refractive plano-convex microlenses 30 (in this case carried on a support 31) mounted in contact with or closely spaced from the photoresist coating 20 of a substrate 22. A uniform beam of UV light is directed onto the array of microlenses. It will be appreciated that the photomask 30,31 accordingly forms a matrix of dots, with substantial compression relative to the size of the microlenses, at a distance f (the focal length of the lens) behind the mask.

Figure 3 shows the distribution of light waves behind a microlens of 5 microns diameter (and 2.5 microns lens height), which we have calculated by rigorous diffraction theory. This shows that the light is "funnelled" or concentrated into a small "pipe" of approximately 1 micron diameter and greater than 5 microns in length. Accordingly, a depth of focus of greater than 5 microns can be used for printing or imaging a dot approximately 1 micron in diameter.

The microlenses (or other optical elements) may be of any desired shape, e.g. circular, cylindrical, annular, square, rectangular, elliptical, etc., arranged to generate a two-dimensional array of dots, lines, circles, squares, rectangles etc. on the photoresist coating.

The photomask may be in direct contact with the photoresist coating, for example under vacuum conditions, so that the photomask (which is preferably flexible or conformable) follows any variations in the flatness of the substrate carrying the photoresist.

Instead, the photomask may be positioned at a short distance (up to 5 microns) from the photoresist coating: in this case, the photomask is rigid and therefore self-supporting.

Referring to Figure 4, the self-imaging effect (Talbot effect) may be used to image the matrix pattern onto the photoresist layer 20, when positioned at the correct distance behind the microlens array 30, i.e. in one of the succession of Talbot planes, spaced at successive distances ΔZ_T behind the focal plane, where

$$\Delta Z_T = \frac{\lambda}{1-\sqrt{1-\lambda^2/d^2}}$$

λ being the wavelength of light used and d being the fundamental period of the microlenses or other optical elements. Here again, the photomask array is rigid and self-supporting. Also, a compression ratio is achieved comparable to the arrangement of Figure 2.

Figure 5 shows use of the fractional Talbot effect, using a mask 40 in the form of a binary phase mask (having a matrix of transparent areas 42, e.g. square in shape). Light passed through this mask forms a Fresnel image of this pattern, with a pure amplitude modulation, at a distance of 0.5 Z_T behind the mask: by placing a substrate at this position, having a photoresist coating, the matrix of squares is printed in that photoresist coating. Again, a substantial compression ratio can be achieved.

A further advantage of the arrangements which use the Talbot effect or the fractional Talbot effect is that the substrate on which the required pattern is to be imaged is placed at a significant distance from the mask: this is a necessary or desirable condition for certain applications.

It will be appreciated that the beam of light which is incident on the array of optical elements is uniform, that is to say it is unmodulated and does not carry any information. The pattern which is formed on the photoresist layer is created entirely by the pattern of the optical elements in their array.

CLAIMS

1) A photomask arrangement which comprises an array of optical elements and means for providing a uniform beam of light incident on said array, each optical element being arranged to concentrate light onto a respective point, line or other area of a photoresist layer.

2) A photomask arrangement as claimed in claim 1, in which said optical elements comprise refractive or diffractive microlenses.

3) A photomask arrangement as claimed in claim 1, in which said optical elements comprise diffraction gratings or apertures.

4) A photomask arrangement as claimed in any preceding claim, in which each optical element is 2 to 500 microns in diameter or width.

5) A photomask arrangement as claimed in any preceding claim, in which said optical elements are in contact with said photoresist layer.

6) A photomask arrangement as claimed in any one of claims 1 to 4, in which said optical elements are spaced from said photoresist layer.

7) A photomask arrangement as claimed in one of claims 1 to 4, in which the photoresist layer is spaced from the optical elements to make use of the self-imaging (Talbot) effect.

8) A photomask arrangement as claimed in any one of claims 1 to 4, in which the photoresist layer is spaced from the optical elements to make use of the fractional Talbot effect.

9) A photolithographic method, in which a uniform beam of light is directed onto an array of optical elements, each said

optical element being arranged to concentrate light onto a respective point, line or other area of a photoresist layer.

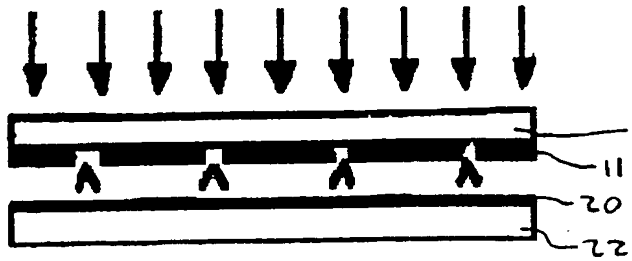

Figure 1

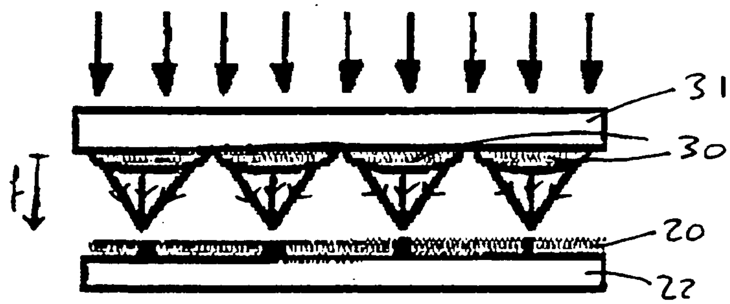

Figure 2

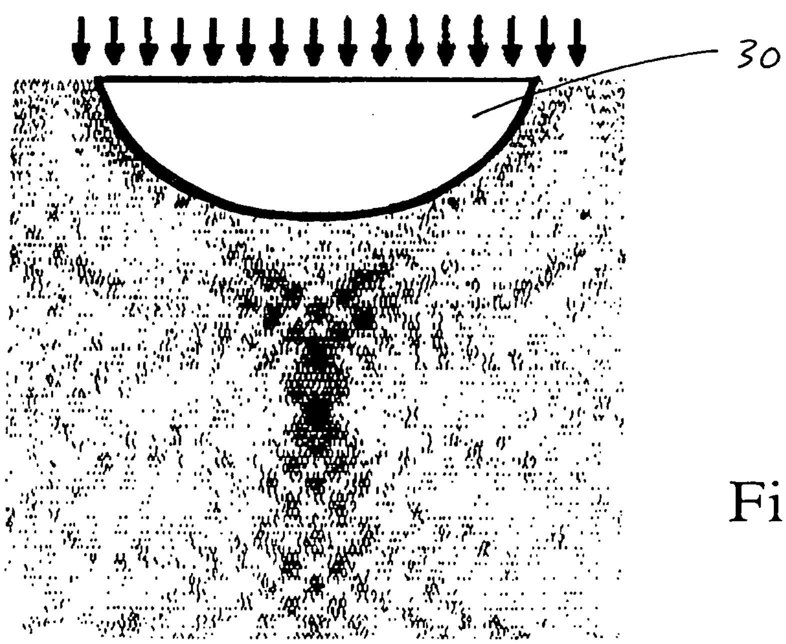

Figure 3

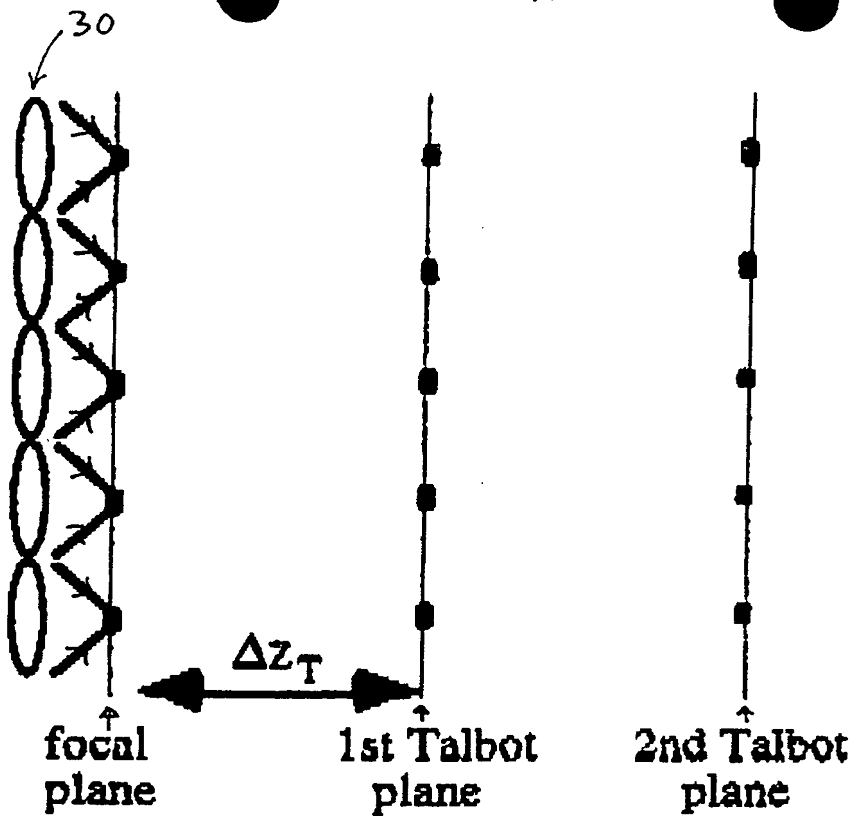

Figure 4

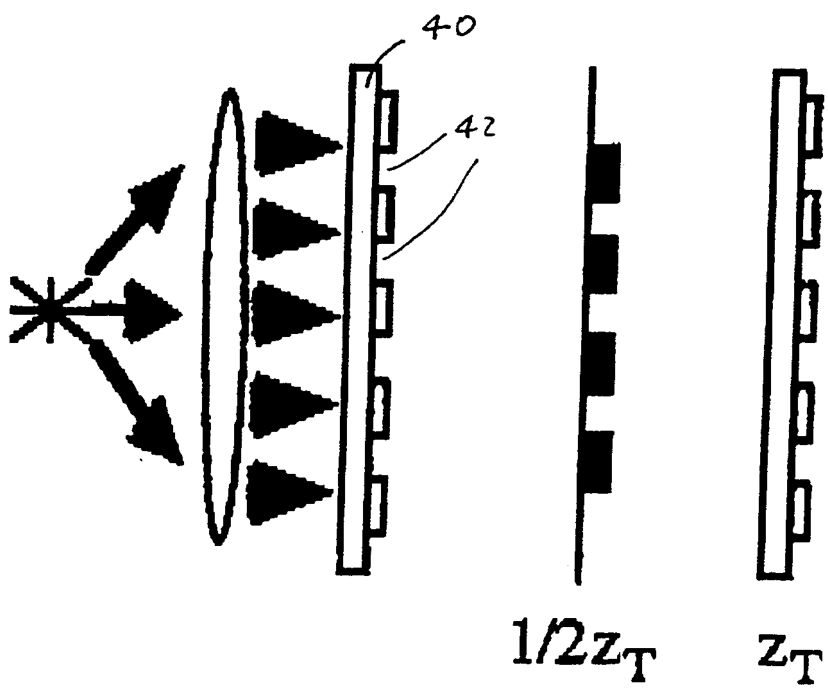

Figure 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 97/01277

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03F7/00 G03F1/14 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 669 (P-1657), 9 December 1993 & JP 05 224396 A (KURARAY CO LTD), 3 September 1993, see abstract ---	1-5,9
X	PATENT ABSTRACTS OF JAPAN vol. 007, no. 030 (P-173), 5 February 1983 & JP 57 181549 A (MASATAKE SATOU), 9 November 1982, see abstract ---	1-5,9
X	US 5 148 322 A (AOYAMA SHIGERU ET AL) 15 September 1992 see figures 19,20,23-26 ---	1-7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Information on patent family members

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